

Grounding and Testing L0 (L1)

--- noise studies ---

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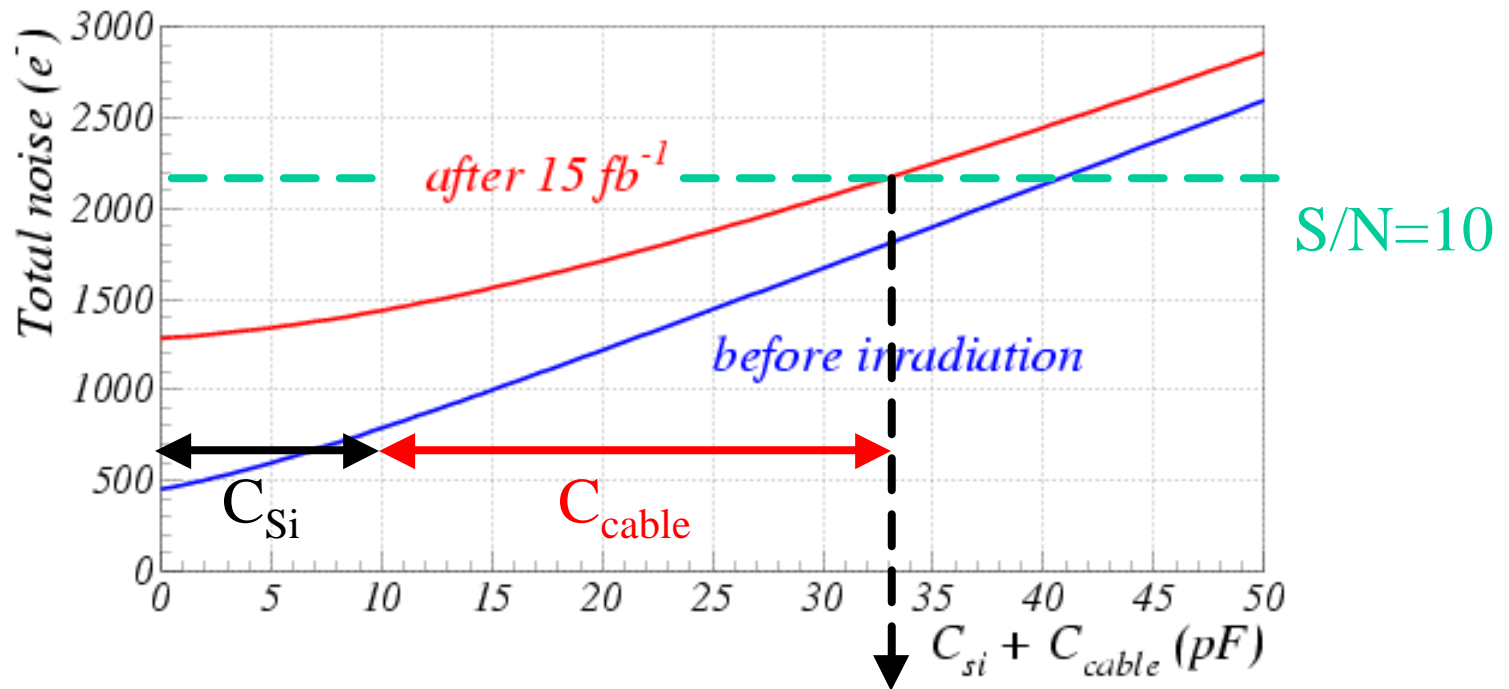
- Introduction of noise issue
- What is going on the other side of the ring (CDF).
- Noise studies using L0 prototypes
- Results for the L1 prototype module
- Grounding studies (done by Marvin, Breese, Mike M)
- Plan
- Conclusions

Introduction of Noise issues for L0

- Goal: $S/N < 10$ after 15(6.5-11?) fb^{-1} .
- Internal contribution: capacitive load by the long analog flex cable.
- External contribution: RF pickup, capacitive coupling...
 ← unfortunately the analog cable works as antenna.
- A few slides to show the current CDF situation.

Noise in terms of Capacitive Load

Total noise estimates VS total capacitance ($C_{si} + C_{cable}$)

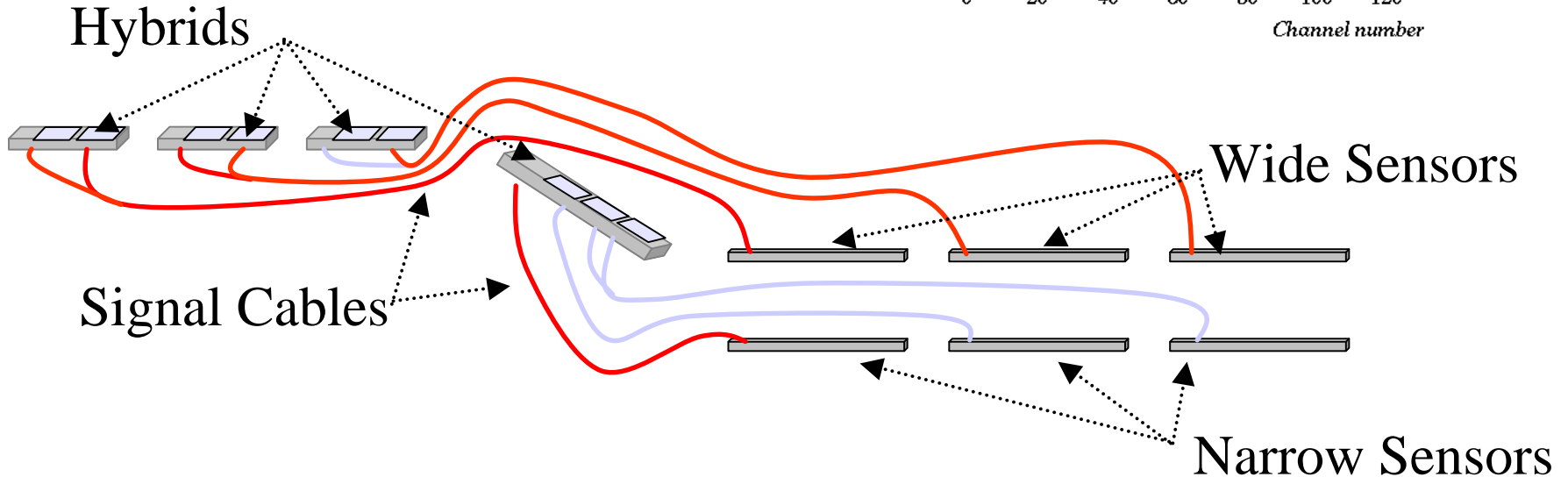
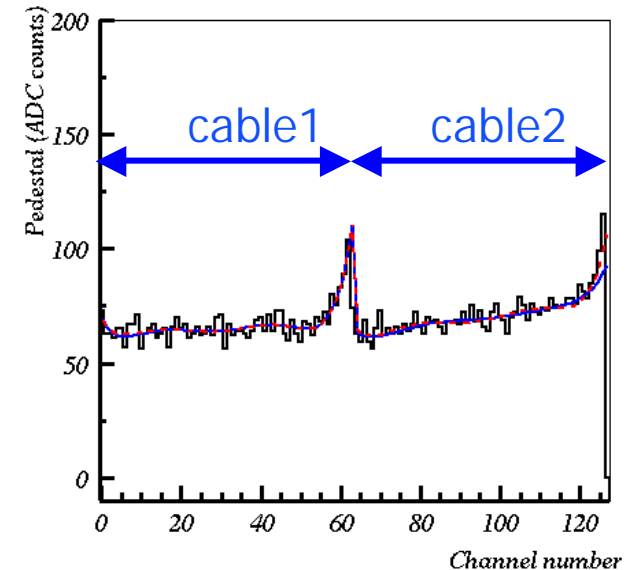


S/N=10 after 15fb⁻¹ $\rightarrow C_{cable} < 23\text{pF}$ for 43.5cm long cable
 $\rightarrow C_{cable} < 0.53\text{pF/cm}$

Lesson from CDF (Pickup on Signal Cables)

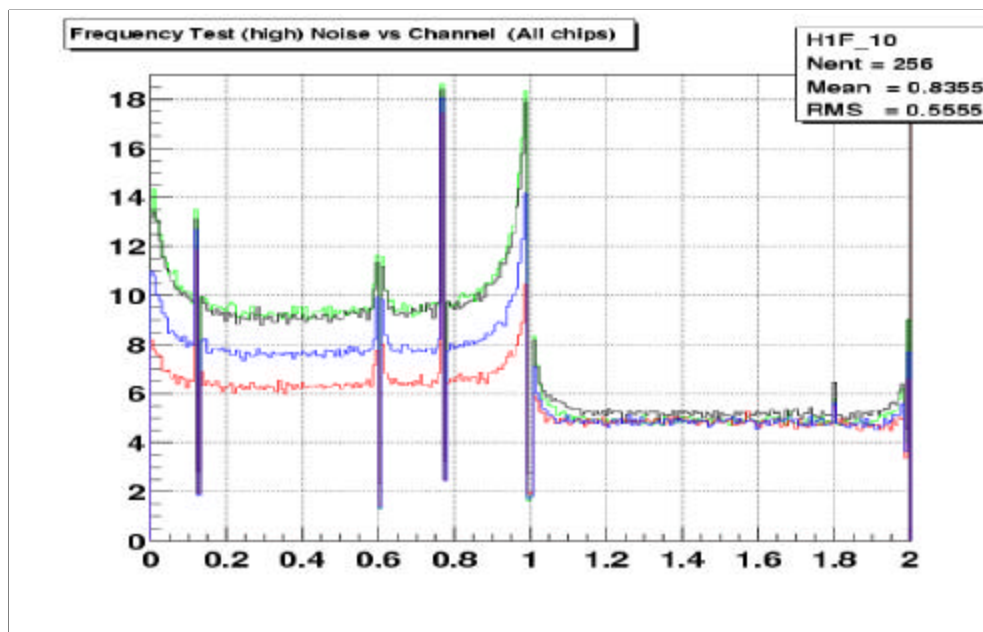
- Noise picked up by analog signal cables
 - Effects are seen at edges of cables, within one sensor
 - Both coherent and incoherent sources
 - Noise shapes
 - Pedestal shifts

HDL=f843 Event=11 Chip=2



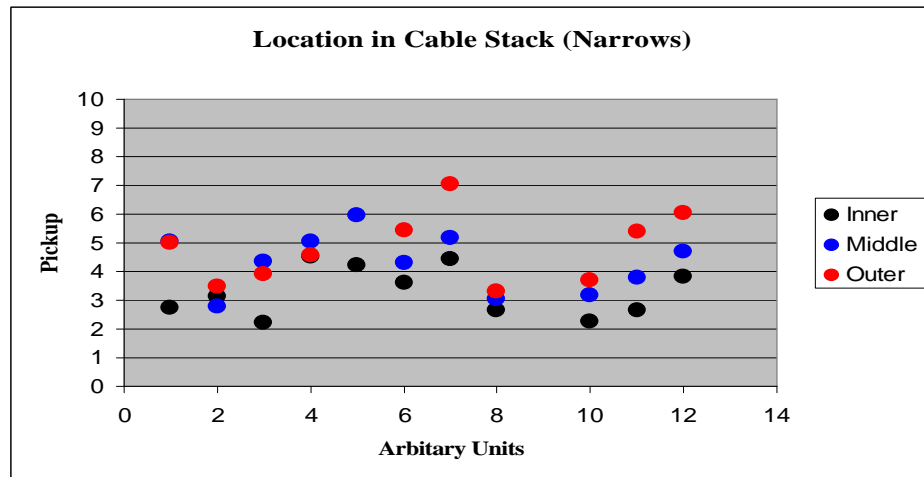
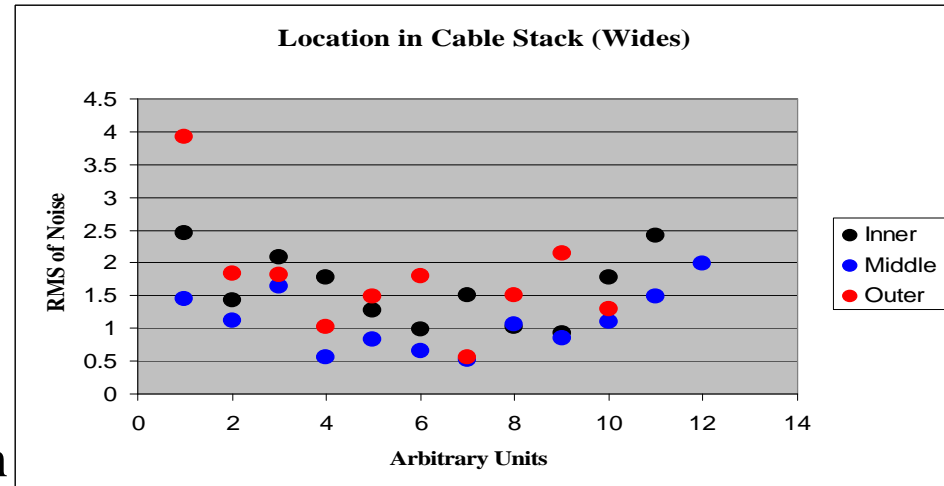
Lesson from CDF (Study of Pickup)

- L00 module in a well-grounded faraday cage
- Insert a noise source (waveform generator)
- Vary amplitude, frequency, geometry, grounding, shielding, state of SVX3D chips when acquiring, etc.
- Conclusions:
 - Cables are the antennae
 - Cables shield one another
 - Pickup increases with frequency
 - Large pickup in some dead-timeless operations, but common-mode
 - Hybrid electronics cables couple to signal cables, depending on geometry
 - Coherent pickup from in-time signals
 - Increased noise due to increased capacitance seen by front-end electronics
 - Properly grounded shield eliminates problem



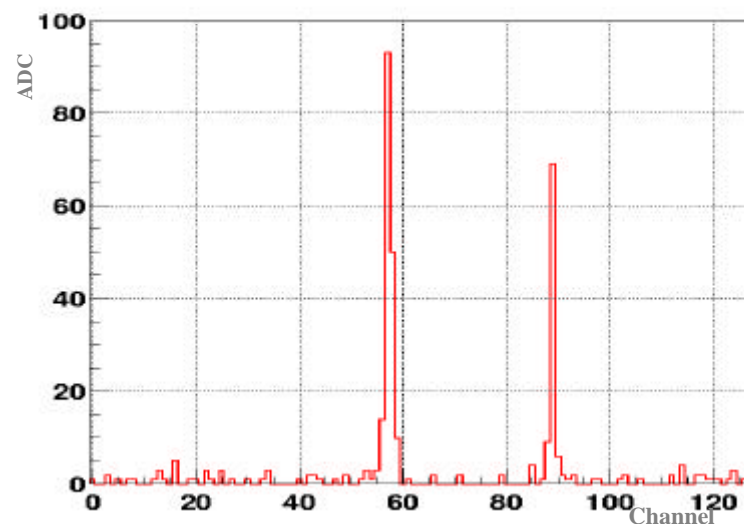
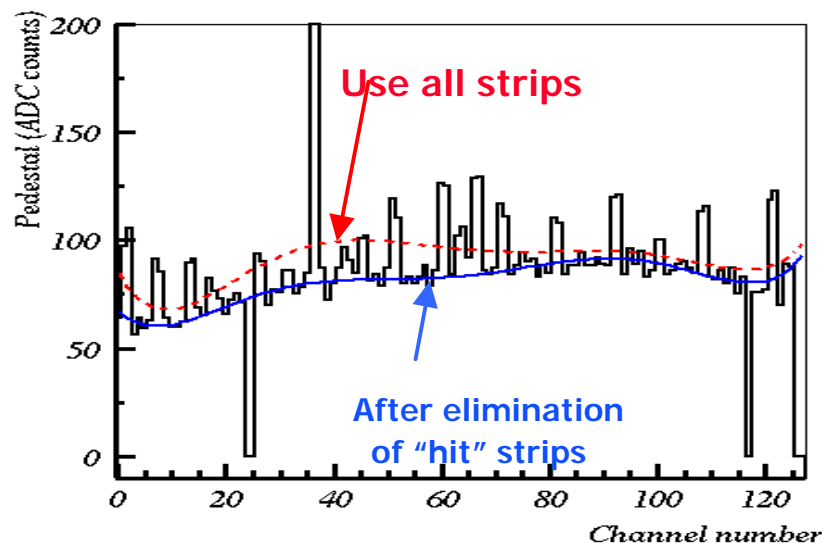
Lesson from CDF (Correlations in Data)

- CDF data exhibits patterns consistent with bench studies
 - Location in cable stack important
 - Wide modules with cables in the middle of stack have least pickup
 - Noise from above & below
 - Narrow modules chip's with innermost cable have least pickup
 - Noise source is above
 - » Beam-pipe, C-fiber support not source of noise
 - Less pickup on west than east
 - Shield grounded on west
- Has other structures not yet understood



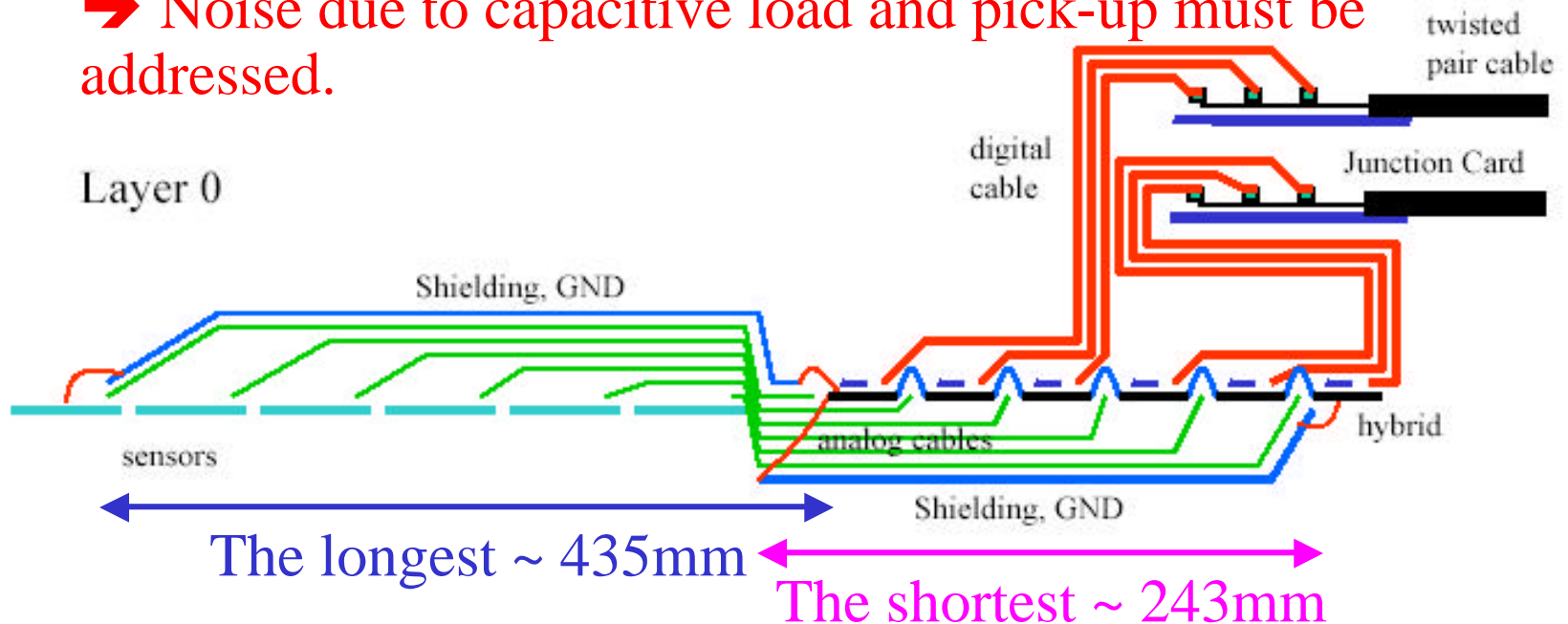
Lesson from CDF (Solution: Fit for Pedestal)

- Problem solved offline
 - Readout all strips in L00
 - Use this information to fit for an event-by-event pedestal
 - χ^2 fit to Chebyshev polynomials
 - Tested by embedding MC clusters in data
 - 95% efficiency with 95% purity
 - No impact on cluster size or centroid resolution
 - Implications for CDF
 - L00 can't be in online track trigger
 - Readout time may be a bottleneck

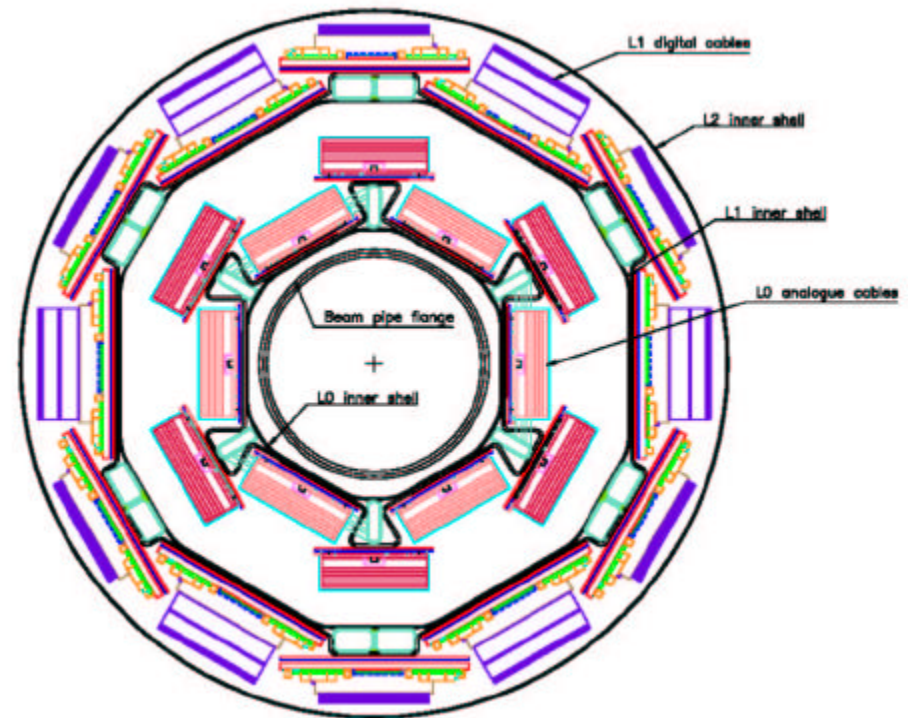
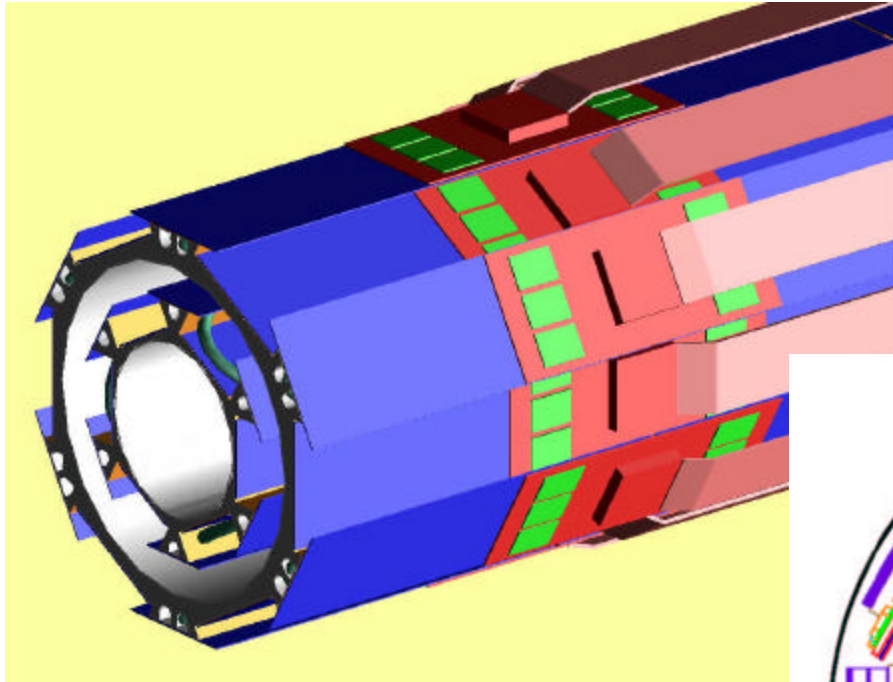


Conceptual Design of L0

- SVX4 chip cannot sit on the sensors because of the cooling and space issues.
 - Signal must be read out from the sensor to the chip.
 - Also bias voltage and its return must be provided.
 - Low mass analog flex cable.
 - Noise due to capacitive load and pick-up must be addressed.

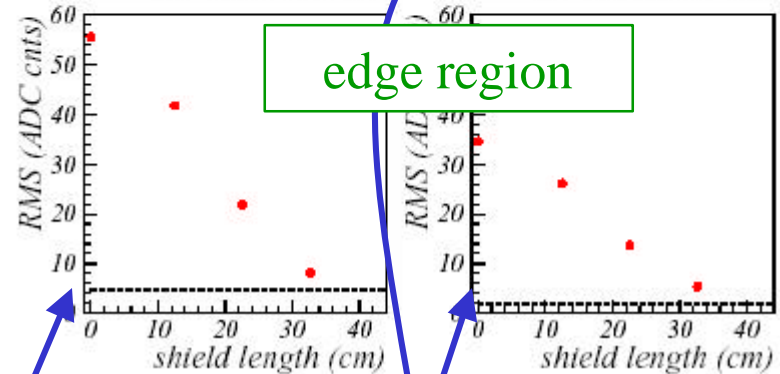
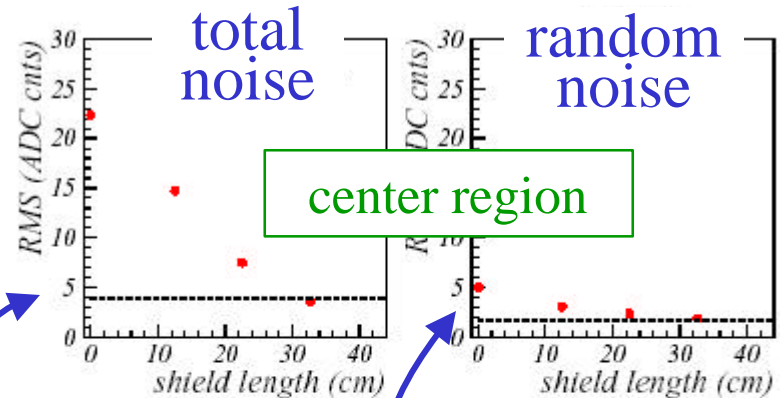
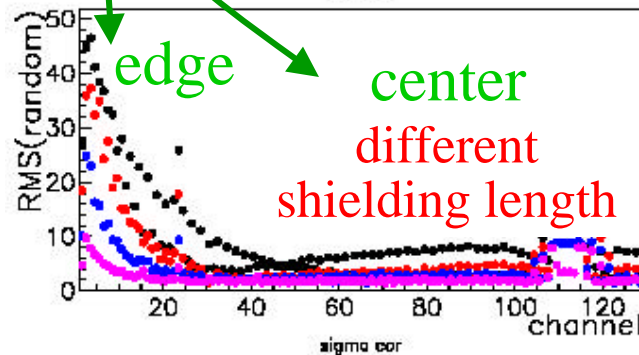
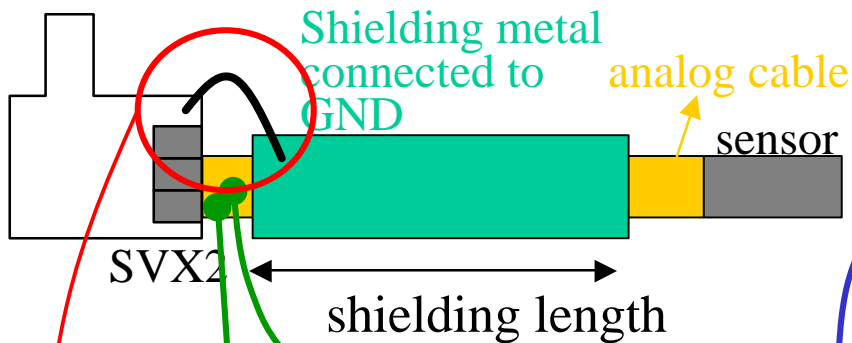


L0/L1 Design



Shielding

- RF pick-up by the analog cable.
- No external but shielding (= aluminum foil) only around the analog cable.

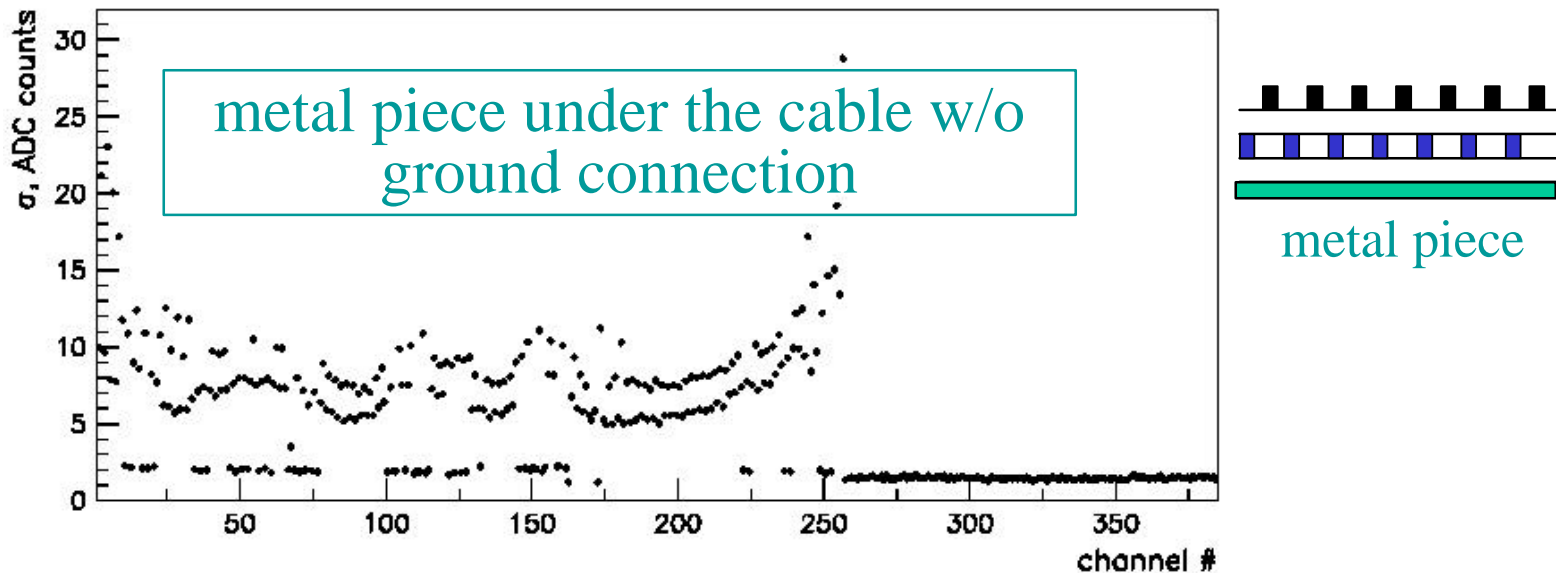


Noise level w/ ext. shielding

better than connecting to the purple card

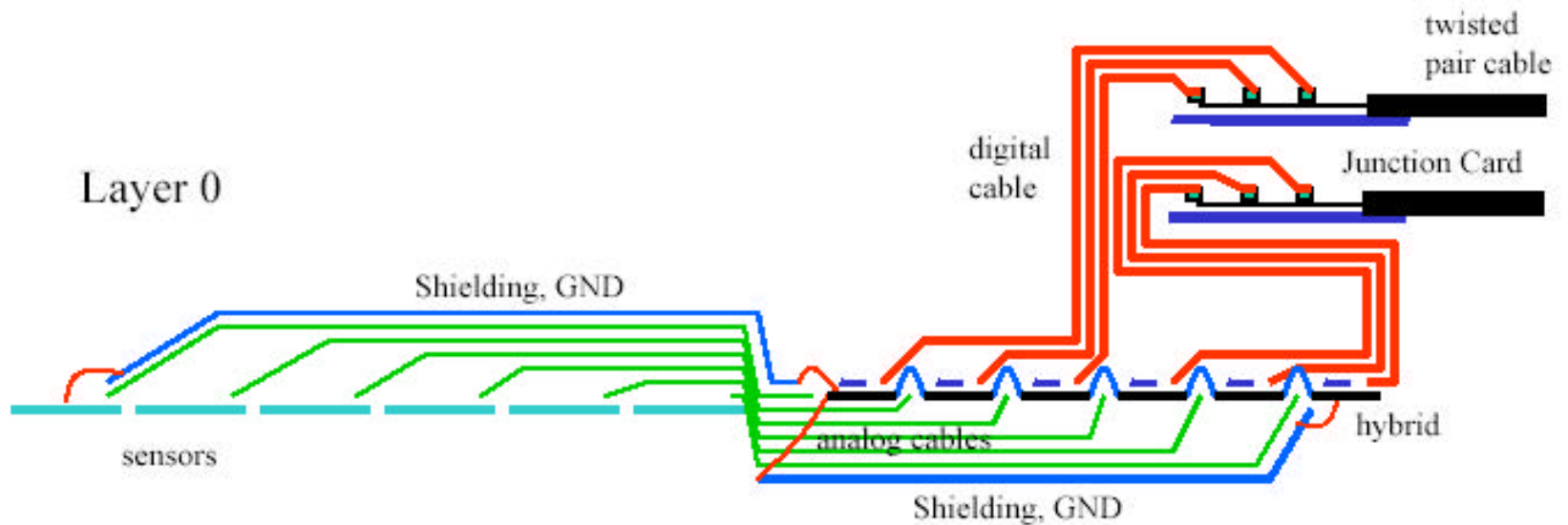
Shielding (cont'd)

- Must be careful about capacitive coupling to nearby floating metal.



- Clear even-odd effect indicates capacitive coupling to the analog cable. ← Distance between the traces to the metal; top-metal $\sim 100\mu\text{m}$, bottom-metal $\sim 50\mu\text{m}$.

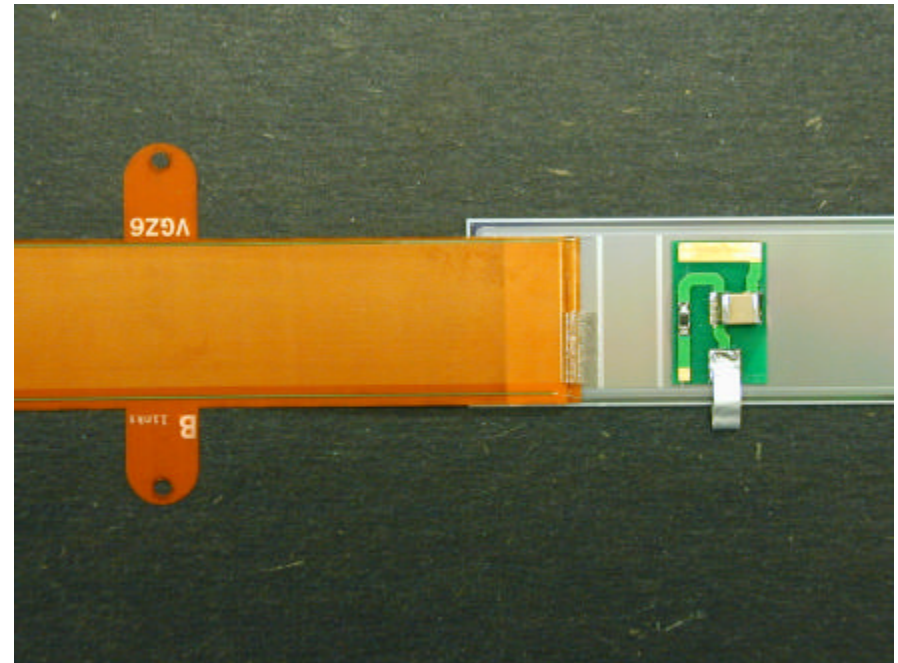
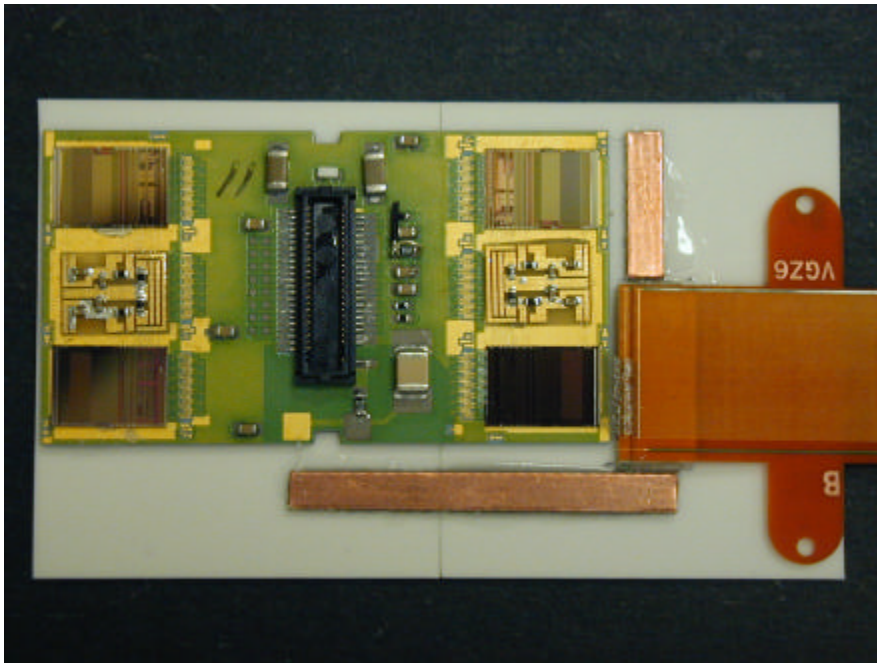
Shielding (cont'd)



- Shielding on the bottom.
- Is there space? How do we connect?

L0 Prototype with SVX4

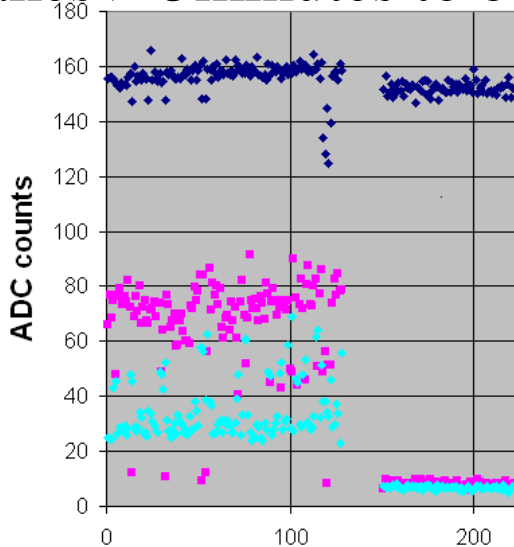
- First prototype using new SVX4 chip.
 - Large capacitive load
 - Long analog cable ← signal transmission
- L1 prototype hybrid with SVX4.



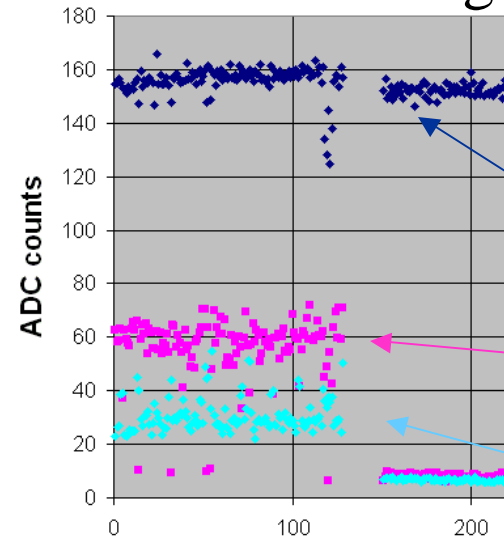
Noise stability

It takes > 5 minutes to be stable after turning HV on.

1st

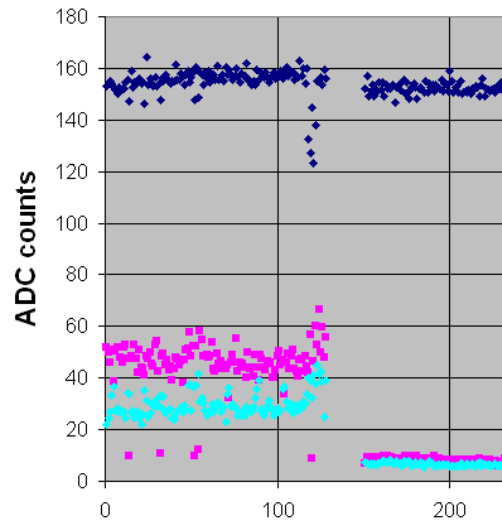


2nd

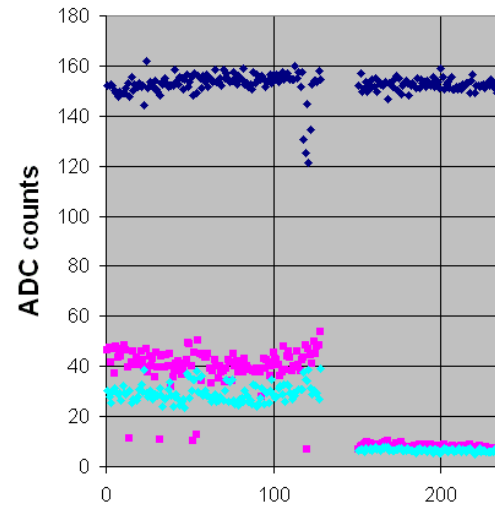


pedestal
total noise
(x10)
differential
noise (x10)

3rd

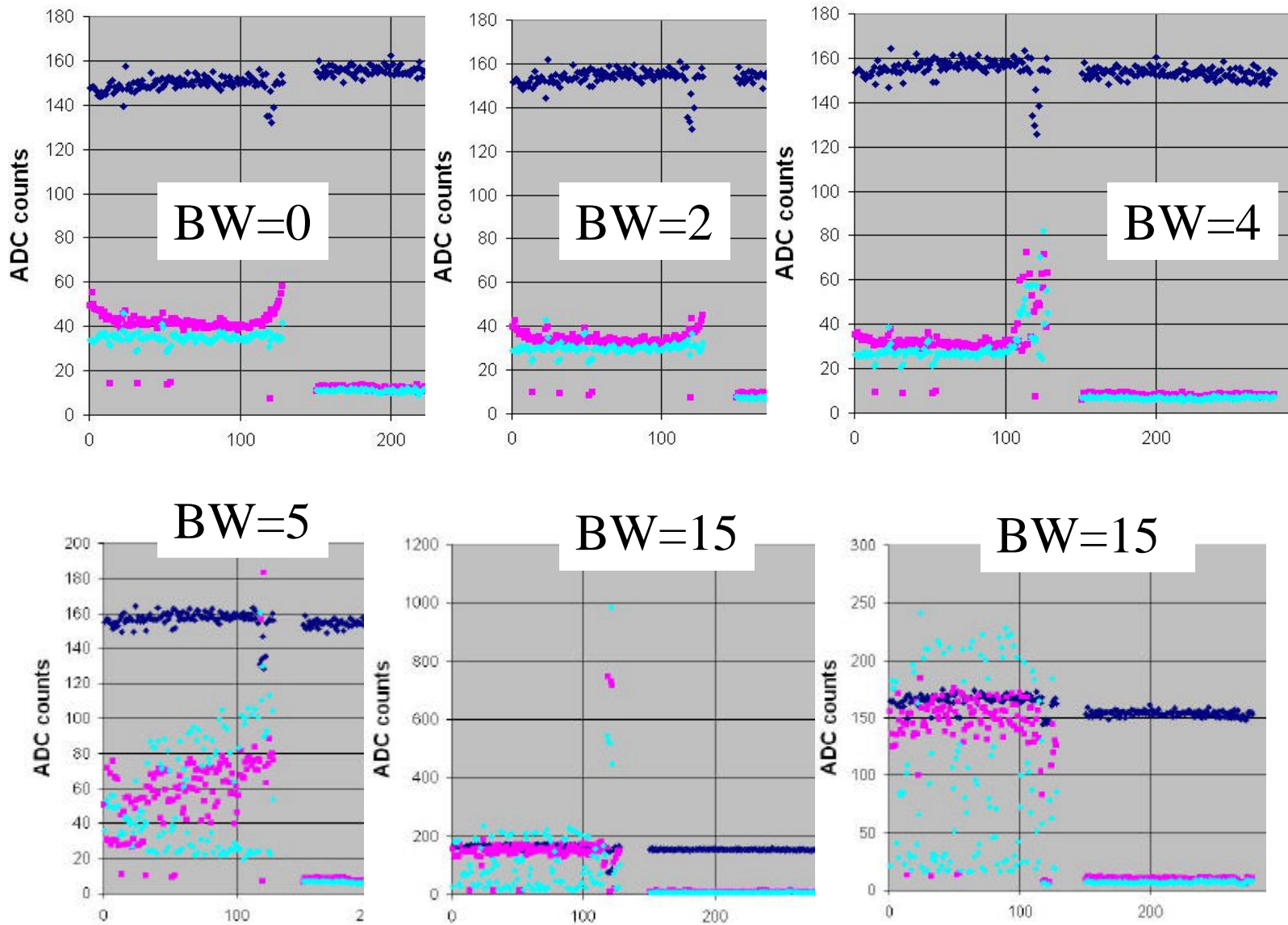


4th



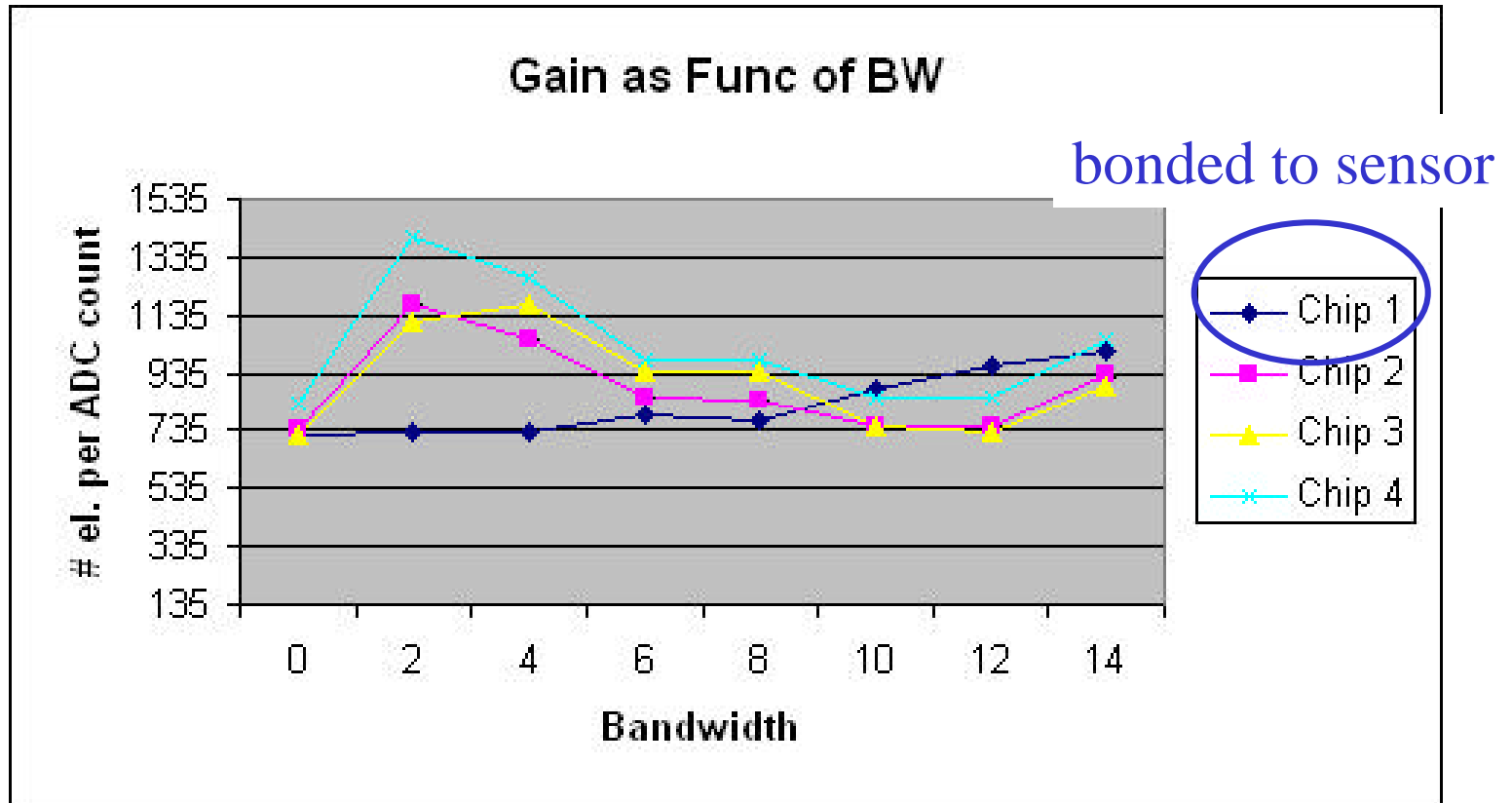
Nothing changed. Just wait order(1minute) each.

BW or Rise Time Dependence




Gain measurement by L0 Prototype

by Sara



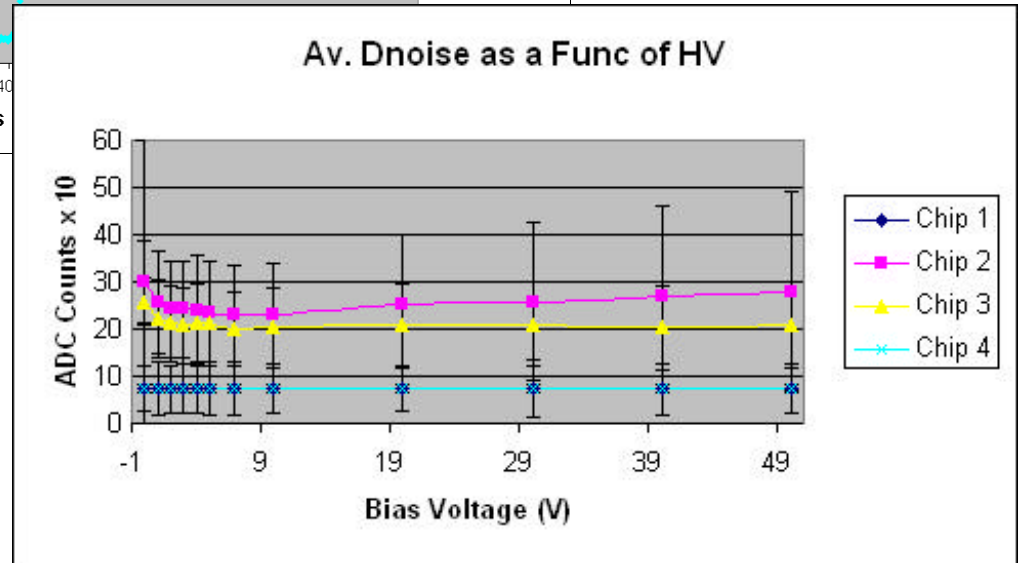
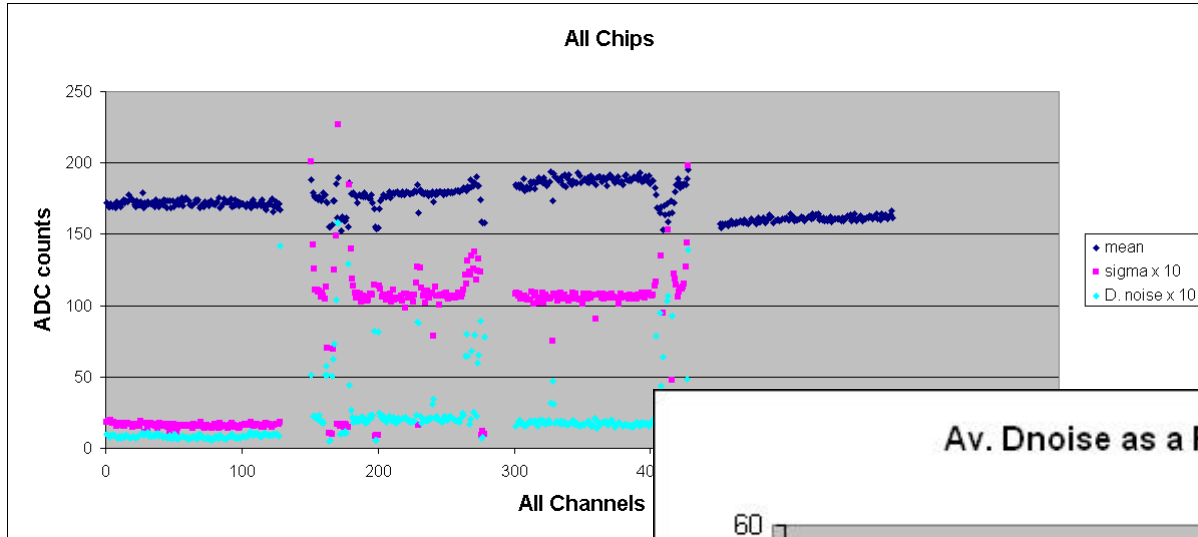
- Consistent with bare chip measurement with $\sim 30\text{pF}$ load.

Noise Level of L0

- BW=4 as a baseline; the rise time is close to 70ns for 33pF of external load.
 - SVX4 front end performance;
 $ENC = 300 + 41C$ (pF) @ fixed rise time of 70ns.
 - #electrons / ADC count is measured as ~ 700 .
Gain measurement with external charge injection (33pF load) consistent with the measurement for the actual L0 prototype with cal_inject by Sara (assuming 25fF of C_{cal}).
 - Random noise for non-loaded chip ~ 0.7 ADC count = 500e.
 - $ENC = 500 + 41C$ (pF) is, thus, good reference.
 - $C(\text{sensor})=10\text{pF}$, $C(\text{analog cable})=15\text{pF} \rightarrow C(\text{total}) = 25\text{pF}$
 \rightarrow expectation = 1500e.
 - Measured random noise ~ 2.7 ADC count = 1900e.
 - $1900 = 500 + 41C \rightarrow C(\text{total}) = 34\text{pF}$
- 

L1 Prototype Module

by Sara

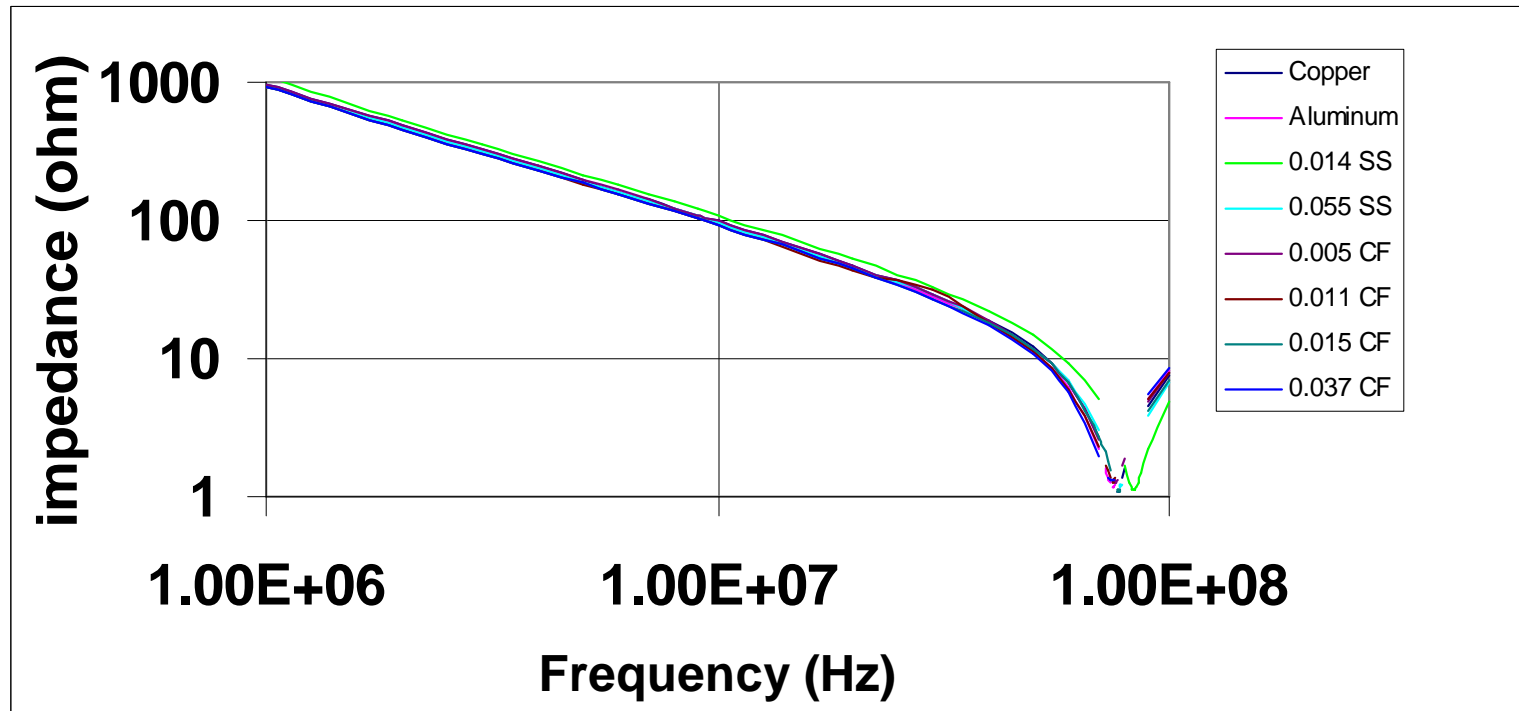


- Depleted at only 10V?
- Huge common mode noise for the chips bonded to sensor.

Noise Level of L1

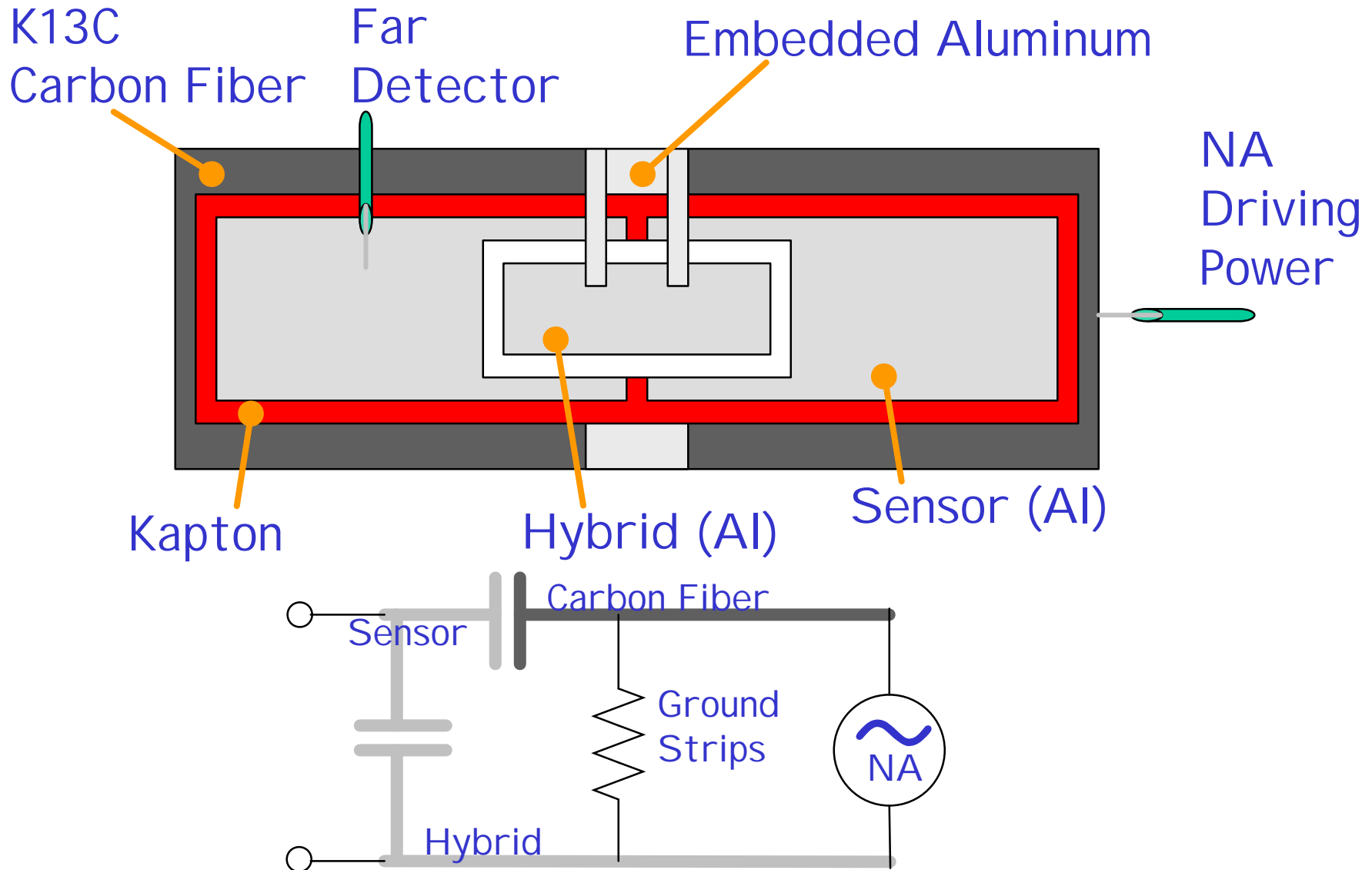
- Differential noise = 2.2 ADC counts
- 2.2 ADC counts $\sim 1500e$
- Non-loaded chip has similar noise level as L0.
→ use the same reference formula for ENC.
 $ENC = 500 + 41C(pF) = 910 e$ --- expectation
- Measured noise level is larger than expectation by 40%.
- $\sqrt{(N_{obs}^2 - N_{expect}^2)} = 1200e$ for L1
- $\sqrt{(N_{obs}^2 - N_{expect}^2)} = 1200e$ for L0
→ accidental coincidence? Or common source?
- Note: argument here is for differential noise.

Impedance of Carbon Fiber



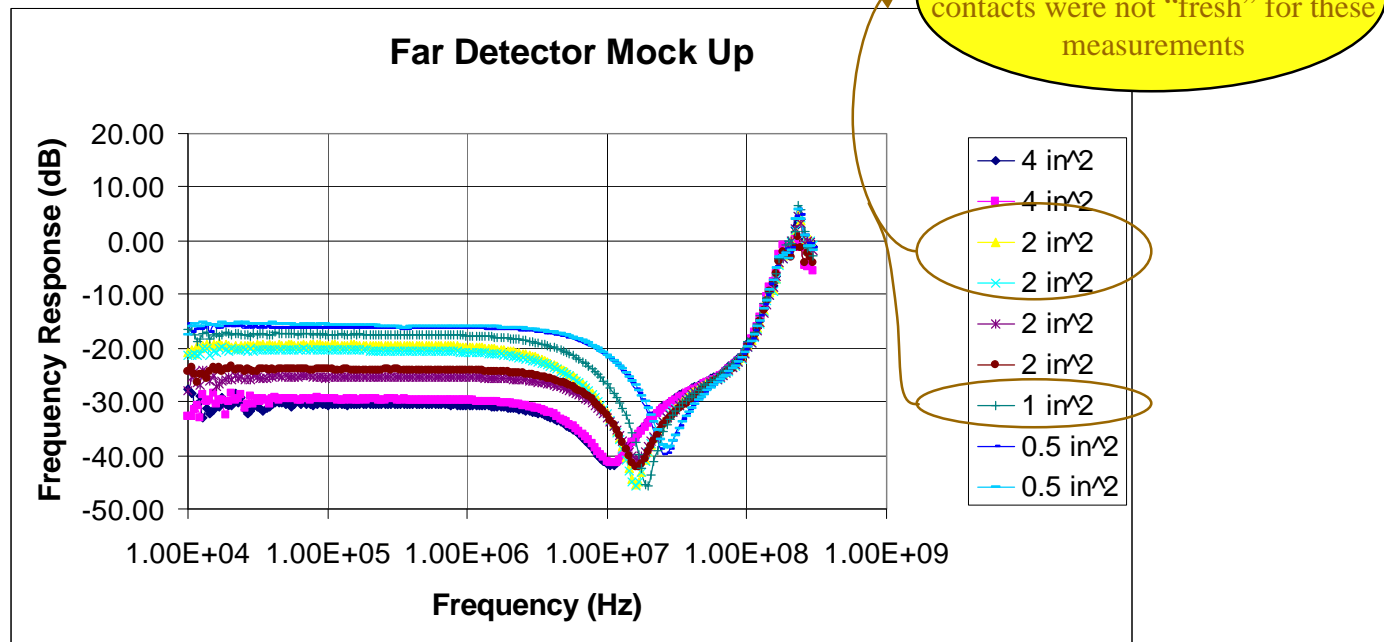
- Carbon Fiber (CF) support structure is regarded as a conductor for high frequency.

L0/L1 Mock-up



L0/L1 Mock-up

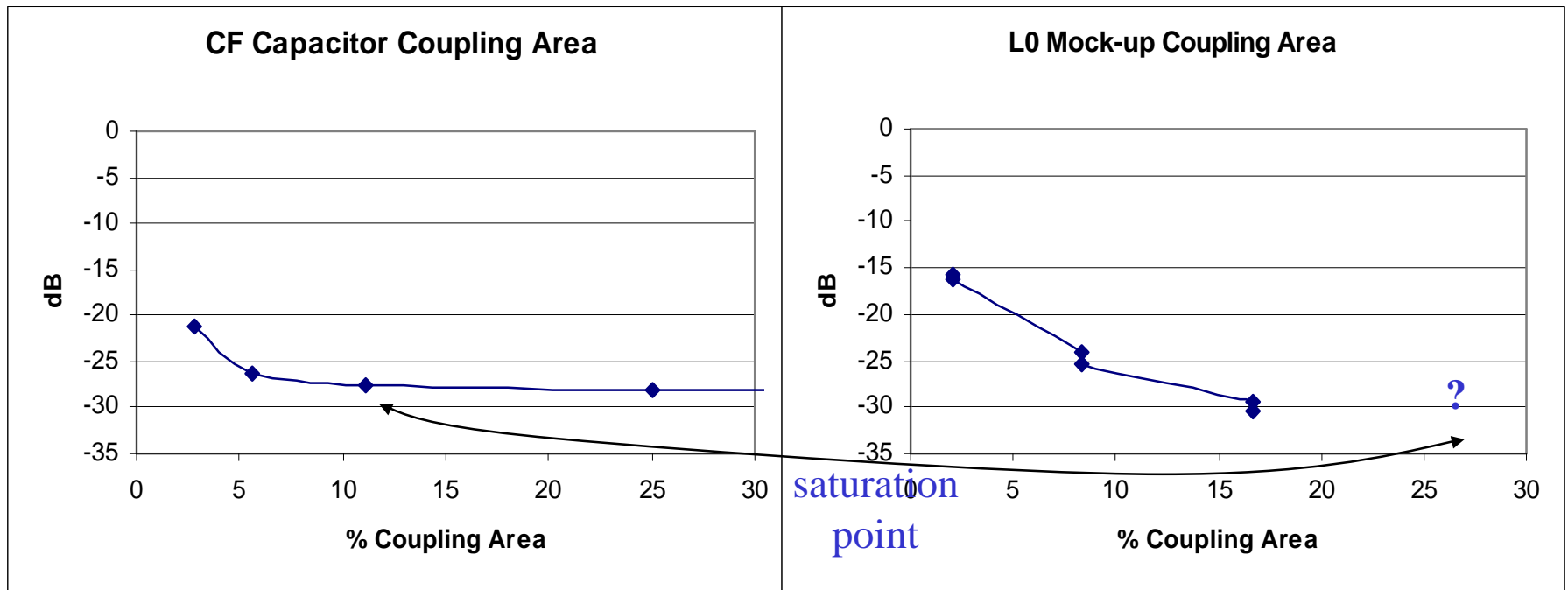
- Studied transfer functions from the C fiber to the “sensor”
 - Varied the amount of C fiber area covered by embedded aluminum
 - $0.5 \text{ in}^2 \rightarrow 4 \text{ in}^2$ (2% \rightarrow 17%)



- Quality of the electrical contact is crucial
- Varying the number and size of shorting strips had no significant effect

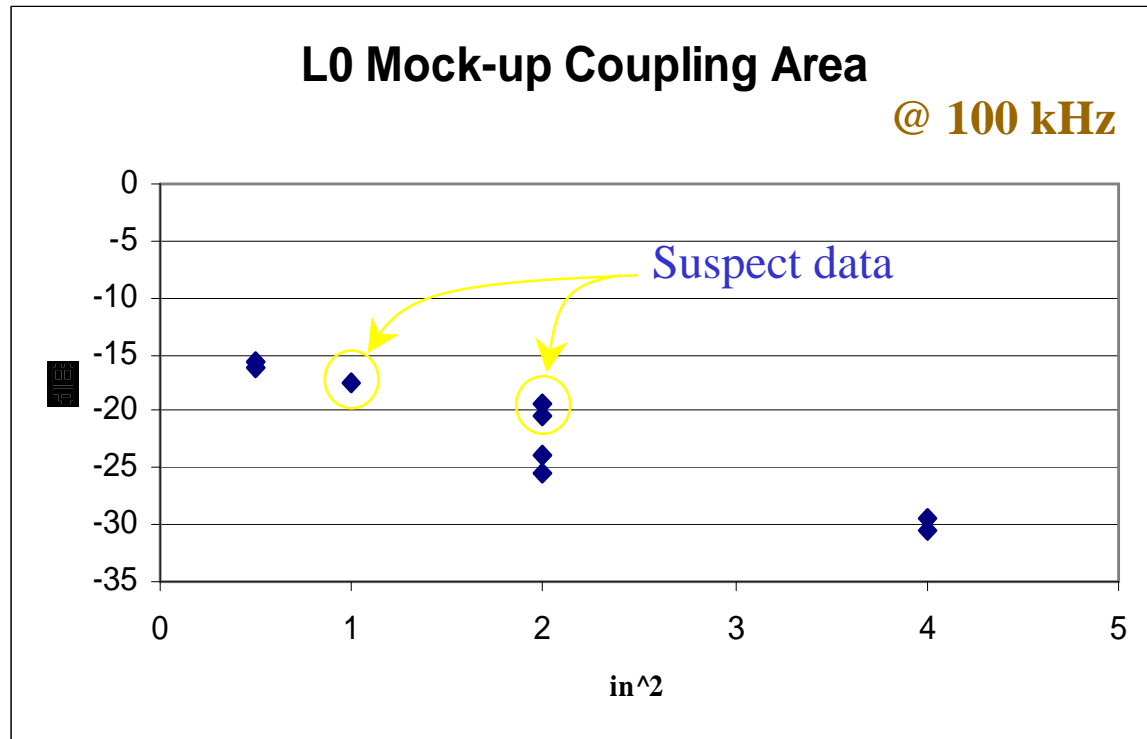
Carbon Fiber Coupling

- Comparison of coupling to the simple CF capacitor with a somewhat subjective selection of L0 Mock-up coupling data



- Estimate 25-30% coverage by embedded AI is needed for maximum attenuation

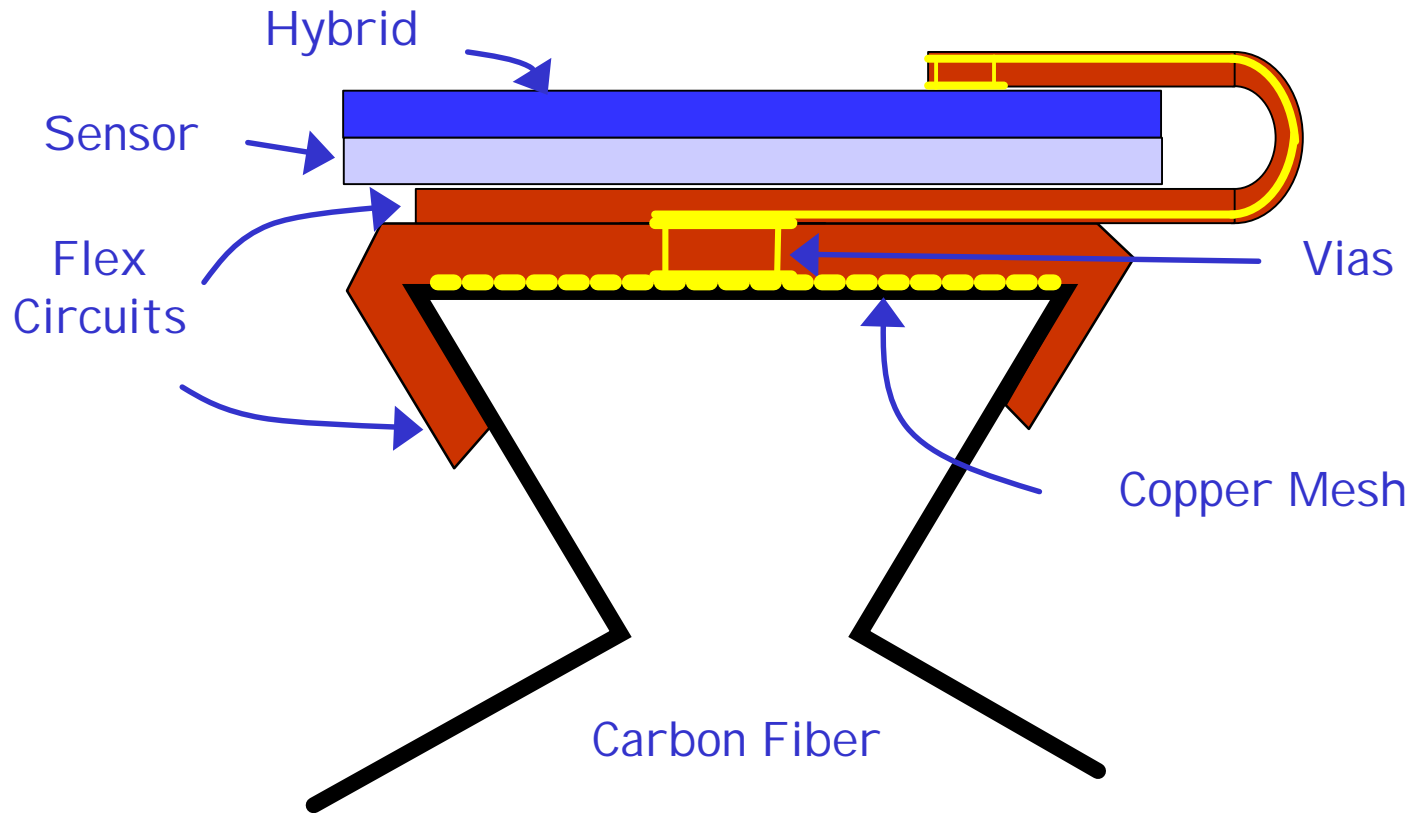
CF Coupling (cont'd)



- Not only a fraction of area to be covered, but also the absolute area may be matter.

Conceptual Design of Grounding

- A significantly more complicated, though considerably more robust coupling concept...



Conclusions

- Both L0 and L1 prototype works.
 - ← confirmation of baseline design (except L0 hybrid).
- Gain of the L0 prototype consistent with the expectation by SVX4 performance.
- L0 noise higher than expectation.
- L1 module also has high noise.
- Noise behavior must be addressed in both L0 and L1 prototypes.
 - crucial for advance studies, such as frequency dependence study to decide shielding material/way.
- Grounding scheme is proposed by Marvin et al.